# A GRAPHICAL STUDY OF THE EPIDEMIOLOGY OF POLIOMYELITIS.

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Received for publication February 4, 1917.

THE poliomyelitis epidemic of 1916 differed from previous outbreaks only in size; but the magnitude of the problem has stimulated investigation to an unprecedented degree. Most of the work on this disease, however, has been limited to the experimental studies of the laboratory, while the wealth of available epidemiological material remains almost untouched. The studies of the Massachusetts State Board of Health in earlier outbreaks and of the United States Public Health Service in the present one are brilliant exceptions. It seems likely that a detailed study from different viewpoints of the characteristics of poliomyelitis as it occurs in nature may throw important light upon the factors concerned in its causation. At the suggestion of Professor C.-E. A. Winslow, Curator of Public Health in the American Museum of Natural History, I have therefore undertaken such a study, which points clearly to the existence of three such factors, two of them well-known and a third, which has not so generally been recognized.

The results of this study can be presented best in graphic form with only brief necessary comment.

## THE EPIDEMIC SPREAD OF THE DISEASE.

The 1916 outbreak offers excellent evidence of the existence of the first factor concerned in the spread of poliomyelitis, viz., communicability. The epidemic began in Brooklyn, from which locality it quickly spread to the remainder of New York City and to New Jersey, the largest number of cases being reported in each of these places for the week of August 12, followed one week later by Connecticut and New York State, and by Pennsylvania in the week of August 26. From the peak in each case there was a more or less rapid decline. (See charts published in AMERICAN JOURNAL OF PUBLIC HEALTH, 1917, Vol. VII, p. 118.)

The mapping of the cases as reported by months in different states indicates that the disease is a communicable one and must have been carried mainly by human agencies, since it followed the routes of travel. In Connecticut the epidemic was confined chiefly to the main railroad line between New York and Boston. The epidemic passed from New York City in the form of a great wave, the territory first infected clearing up first.

The wave-like character of the epidemic is shown still better where the cases per 100,000 population are given by counties, and the counties plotted according to their distances from Brooklyn. The crest of the wave

progressed steadily across the state in New Jersey and also in New York. (See chart, AMERICAN JOURNAL OF PUBLIC HEALTH, 1917, Vol. VII, p. 119.)

It will be noticed that those counties more or less isolated from main routes of travel escaped with a very low incidence.

The fact that in the districts first affected (Brooklyn, the southeastern counties of New York and the northeastern counties of New Jersey) the diseases began to subside before it reached its maximum in the regions beyond strongly suggests the burning out of susceptible material in these communities and is in line with the view of Frost and others that in a severe outbreak of poliomyelitis practically the whole population is exposed to infection.

### THE FACTOR OF SEASON.

A second fundamental factor in the prevalence of this disease is its marked preference for the summer season. This is a puzzling phenomenon since all other diseases spread as poliomyelitis is believed to be spread, by the exchange of nose and throat secretions by human contact, are cold weather diseases. Professor Winslow has pointed out that a summer prevalence is suggestive of either an insect factor or an intestinal factor of some sort in the etiology of the disease.

The influence of season was very clearly shown in the 1916 epidemic. In the communities first affected the disease naturally decreased with the exhaustion of susceptible material; but even in the outlying districts where the epidemic broke out at a later date and could not have attained its maximum severity it dropped off in September with the onset of cool weather and practically disappeared in October. Chart 1, showing the incidence of the disease in five New Jersey counties, shows this very clearly. Essex and Passaic counties were severely affected early in August; Monmouth, not until late August; Atlantic and Gloucester counties, not until September; yet when cold weather came on the cases in the latter counties dropped off at once without ever reaching the maxima attained in the regions first attacked, and, apparently, before the available susceptible material could have been exhausted.

In order to see how far the principle of summer prevalence has held, I have studied the records of 52 epidemics, which have been reported during the past seventy-five years in different parts of the world. Chart 2 shows how generally the outbreaks have begun in the warmer months, though they have sometimes persisted through the fall. The detailed history of eleven typical epidemics is shown in Chart 3. The peak usually occurs in August or September with practically all the cases between the first of June and the last of November. A few small epidemics occurring in different localities have extended into the winter. In each one there is the usual summer rise and drop with a second rise in winter. The number of outbreaks and the number of cases in these outbreaks is so small in comparison with the others, however, that they do not materially affect the general conclusions brought out in Chart 3.

### Influence of Rainfall.

The fact that epidemics of poliomyelitis often occur during dry seasons has been occasionally noted and was strongly emphasized by Hill in the case of the Minnesota epidemic of 1909. In the course of my studies my attention was drawn to the fact that August, 1916, had the lowest rainfall recorded for that month in 46 years. In order to see whether this relation was in any sense a general one I have studied thirty-four epidemics (see Table I), the results being summarized in Table II. It will be seen that 76 per cent. of the epidemics began in deficiency months and in 29 per cent. the dry weather continued clear through. Twenty-four per cent. of the epidemics began in excess months, but in no instance did the wet weather continue clear through.

Chart 4, selected from the large series of outbreaks plotted, show the conditions which have generally obtained, although there have been a few exceptional instances of epidemics during wet seasons. Chart 5 brings out the broad relation between rainfall and the incidence in the epidemics for which full data were available.

TABLE I.

| *Locality and Year.* | *Cases.* | *Month.* | *Precipitation.* | | |
|---|---|---|---|---|---|
| | | | | Departure from normal. | |
| Stockholm, 1887, | | Aug. | 44. (mm.). | -29. | + |
| | | Sept. | 60. | | 18. |
| Poughkeepsie, N. Y., 1899, | | July | 5.56 (*in.*) | | 1.29 |
| | | Aug. | 1.68 | 2.93 | |
| North Adams, Mass., 1894, | | Aug. | 6.09 | | 1.7 |
| | | Sept. | 2.20 | .8 | |
| Stockholm, 1895, | | June | 25. (mm.) | 14. | |
| | | July | 114. | | 51. |
| | | Aug. | 72. | 1. | |
| | | Sept. | 41. | 1. | |
| Trondhjem, Norway, 1905, | | Apr. | 53. | | 10. |
| | | May | 36. | | |
| | | June | 47. | | 6. |
| | | July | 117. | | 52. |
| | | Aug. | 116. | | 28. |
| | | Sept. | 55. | 23. | |
| | | Oct. | 65. | 28. | |
| Vienna, 1897, | | June | 79. | 5. | |
| | | July | 206. | | 128. |
| | | Aug. | 39. | 23. | |
| | | Sept. | 42. | | |
| | | Oct. | 51. | | |
| | | Nov. | 11. | 21. | |
| Stockholm, 1899, | | July | 49. | 14. | |
| | | Aug. | 23. | 50. | |
| | | Sept. | 115. | | 73. |
| Gloucester, Mass., 1900, | | June | 1.85 (in.) | 1.2 | |
| | | July | 2.69 | .8 | |
| | | Aug. | 2.46 | 2.0 | |
| | | Sept. | 4.62 | | 1.7 |
| Ridgeway, Pa., 1907, | | July | 1.32 | 3.69 | |
| | | Aug. | 1.37 | 2.59 | |
| | | Sept. | 5.55 | | 2.16 |

| *Locality and Year.* | *Cases.* | *Month.* | *Precipitation.* | | |
|---|---|---|---|---|---|
| | | | | Departure from normal. | |
| | | | (in.) | − | + |
| New York, N. Y., 1907, | | July | .89 | 3.6 | |
| | | Aug. | 3.24 | 1.3 | |
| | | Sept. | 8.33 | | 4.6 |
| | | Oct. | 4.78 | | .9 |
| San Francisco, 1901, | | May | .69 | .1 | |
| | | June | .00 | .2 | |
| Cherryfield, Me., 1896, | | July | 6.05 | | 3.0 |
| | | Aug. | 2.90 | .6 | |
| New York, N. Y., 1897, | | June | 2.98 | .3 | |
| | | July | 9.52 | | 5.0 |
| | | | (mm.) | | |
| Saint Foy, France, 1885, | | June | 21. | 44. | |
| | | July | 9. | 70. | |
| St. Girons, France, 1894, | | July | 4. | 8. | |
| | | Aug. | 1. | 25. | |
| Vermont, 1894, | | July | 1.57 | 1.2 | |
| | | Aug. | 1.49 | 2.5 | |
| | | Sept. | 2.88 | .5 | |
| | | | (mm.) | | |
| Umea, Sweden, 1881, | 18 | July | 55.4 | 1.5 | |
| | | | (in.) | | |
| Vermont, 1915, | 9 | Aug. | 2.88 | .9 | |
| | 13 | Sept. | .97 | 3.0 | |
| | 10 | Oct. | 2.74 | .5 | |
| Newark, N. J., 1916, | 197 | July | 3.44 | 1.1 | |
| | 503 | Aug. | .59 | 4.0 | |
| | 89 | Sept. | 2.98 | .6 | |
| Franklin County, Mass., 1908, | 6 | June | 2.7 | .4 | |
| | 28 | July | 2.0 | 1.6 | |
| | 26 | Aug. | 3.7 | .2 | |
| | 5 | Sept. | .3 | 2.4 | |
| Los Angeles, Cal., 1912, | 19 | June | 0.0 | .10 | |
| | 129 | July | 0.0 | .02 | |
| | 89 | Aug. | 0.0 | .03 | |
| Vermont, 1914, | 8 | July | 1.94 | 1.8 | |
| | 88 | Aug. | 2.78 | 1.2 | |
| | 142 | Sept. | 2.36 | 1.0 | |
| | 56 | Oct. | 1.10 | 2.1 | |
| Boston, Mass., 1893, | 8 | Aug. | 6.5 | | 3.2 |
| | 11 | Sept. | 1.6 | 2.4 | |
| Westfalen, 1909, | 9 | June | 64. | 4. | |
| | 28 | July | 114. | | 24. |
| | 57 | Aug. | 104. | | 21. |
| | 75 | Sept. | 92. | | 32. |
| | 147 | Oct. | 57. | 10. | |
| | 42 | Nov. | 72. | | 21. |
| | | | (in.) | | |
| Seattle, Wash., 1910, | 32 | Aug. | .17 | 32. | |
| | 32 | Sept. | 1.04 | 89. | |
| | 15 | Oct. | 4.02 | | 1.14 |
| Buffalo, N. Y., 1912, | 9 | June | .83 | 2.31 | |
| | 68 | July | 1.41 | 1.99 | |
| | 110 | Aug. | 4.00 | | 1.01 |
| | 74 | Sept. | 3.31 | | .13 |
| | 16 | Oct. | 4.25 | | .72 |
| Mason City, Iowa, 1910, | 5 | May | 2.32 | 2.34 | |
| | 14 | June | 1.20 | 4.69 | |
| | 17 | July | .71 | 3.35 | |
| | 3 | Aug. | 4.84 | | 1.24 |
| Stockholm, 1911, | 19 | May | 6. | 29. | |
| | 23 | June | 23. | 16. | |
| | 11 | July | 34. | 29. | |

| *Locality and Year.* | *Cases.* | *Month.* | *Precipitation.* | | |
|---|---|---|---|---|---|
| | | | (mm.) | Departure from normal. | |
| Stockholm, 1911—*Cont'd,* | 24 | Aug. | 32. | −41. | + |
| | 57 | Sept. | 40. | 1. | |
| | 32 | Oct. | 65. | | 6. |
| | 17 | Nov. | 78. | | 39. |
| | | | (in.) | | |
| Minnesota, 1909, | 7 | June | 3.5 | .7 | |
| | 26 | July | 3.84 | .48 | |
| | 58 | Aug. | 4.54 | | 1.15 |
| | 99 | Sept. | 3.16 | .25 | |
| | 87 | Oct. | 1.56 | .82 | |
| | 21 | Nov. | 2.68 | | 1.83 |
| | 10 | Dec. | 1.54 | | .77 |
| Cincinnati, Ohio, | 5 | Aug. | 3.06 | 0.27 | |
| | 44 | Sept. | 7.52 | | 5.21 |
| | 92 | Oct. | 4.54 | | 2.22 |
| | 17 | Nov. | 2.92 | .29 | |
| | | | (mm.) | | |
| Jönköping's Co., Sweden, 1911, | 49 | July | 56.9 | | 2. |
| | 414 | Aug. | 39.9 | 40. | |
| | 313 | Sept. | 29.2 | 15. | |
| | 132 | Oct. | 95.7 | | 55. |
| Älfborg's Co., Sweden, 1911, | 34 | July | 45.8 | 24. | |
| | 106 | Aug. | 37.5 | 78. | |
| | 103 | Sept. | 53.9 | 7. | |
| | 32 | Oct. | 139.4 | | 42. |
| | | | (in.) | | |
| Nebraska, 1909, | 143 | July | 3.9 | | .4 |
| | 137 | Aug. | 2.0 | 1. | |
| | 53 | Sept. | 2.9 | .7 | |
| | 20 | Oct. | 1.1 | .5 | |
| New York, N. Y., 1916, | 313 | June | 3.98 | | .68 |
| | 3443 | July | 3.44 | 1.1 | |
| | 3927 | Aug. | .59 | 4.0 | |
| | 985 | Sept. | 2.98 | .6 | |
| | 258 | Oct. | .63 | 3.0 | |

TABLE II.

| | |
|---|---|
| Total number of epidemics | 34 |
| Epidemics starting in deficiency months | 26 |
| Epidemics starting in excess months | 8 |
| Epidemics occurring entirely in deficiency months | 10 |
| Epidemics occurring entirely in excess months | 0 |
| Total number of months | 123 |
| Number of deficiency months | 82 |
| Number of excess months | 38 |
| Number of months with no change | 3 |

Of these 34 epidemics only 18 were sufficiently well reported so that the number of cases by months could be determined. These 18 were studied as to the number of cases occurring in the deficiency and excess months.

TABLE III.

| | |
|---|---|
| Total number of epidemics | 18 |
| Total number of months | 73 |
| Number of deficiency months | 51 |
| Number of excess months | 22 |
| Total number of cases reported | 13,365 |
| Cases occurring in deficiency months | 11,994 |
| Cases occurring in excess months | 1,371 |

Although only 70 per cent. of the months were deficient in rainfall, 90 per cent. of all the cases occurred during dry seasons.

The relation between the number of cases and the amount of dryness is quite pronounced. In those months when the deficiency of rainfall amounted to 3 to 5 inches, 36 per cent.

of all the cases occurred, 1 to 3 inches deficiency—35 per cent. of the cases, 0 to 1 inch more than 17 per cent. of the cases.

## Summary.

From the charts, maps and tables given the following conclusions concerning past epidemics of poliomyelitis may be drawn:

(1) The disease follows the main routes of travel, indicating that it is probably carried by human agencies. (2) It spreads in waves over the country, the crest progressing steadily away from the focus. This suggests that in severe outbreaks practically everyone is exposed and, after all the susceptibles have been stricken, the epidemic subsides. (3) The seasonal prevalence is quite marked, the large majority of cases occurring between the first of June and the last of November. In the southern hemisphere the seasons are reversed, the epidemics occurring between the first of December and the last of May. (4) Out of 34 epidemics occurring during the last 75 years, 76 per cent. began in months of deficient rainfall and in 29 per cent. of them the dry weather lasted clear through. Twenty-four per cent. of the epidemics began in excess months and in none did the wet weather continue clear through.

In 18 epidemics with a total of 13,365 cases practically 90 per cent. of the cases occurred during deficiency months. The dryer the weather, the greater, in general, has been the number of cases.

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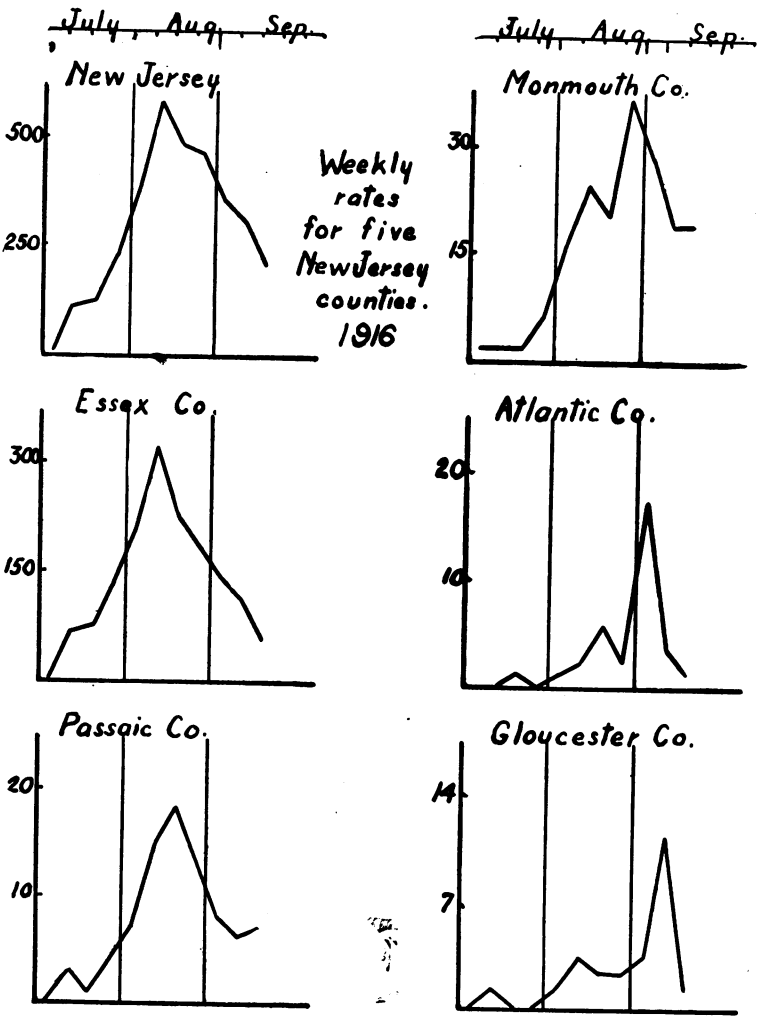


CHART 1. Weekly rates of poliomyelitis for five New Jersey counties, showing how the disease progressed in a wave across the state (Essex, Passaic, Monmouth, Atlantic, Gloucester), and the burning up of susceptible material. When cool weather came on, the epidemic subsided without reaching the maxima attained in the regions first attacked and apparently before all available susceptible material could have been exhausted.

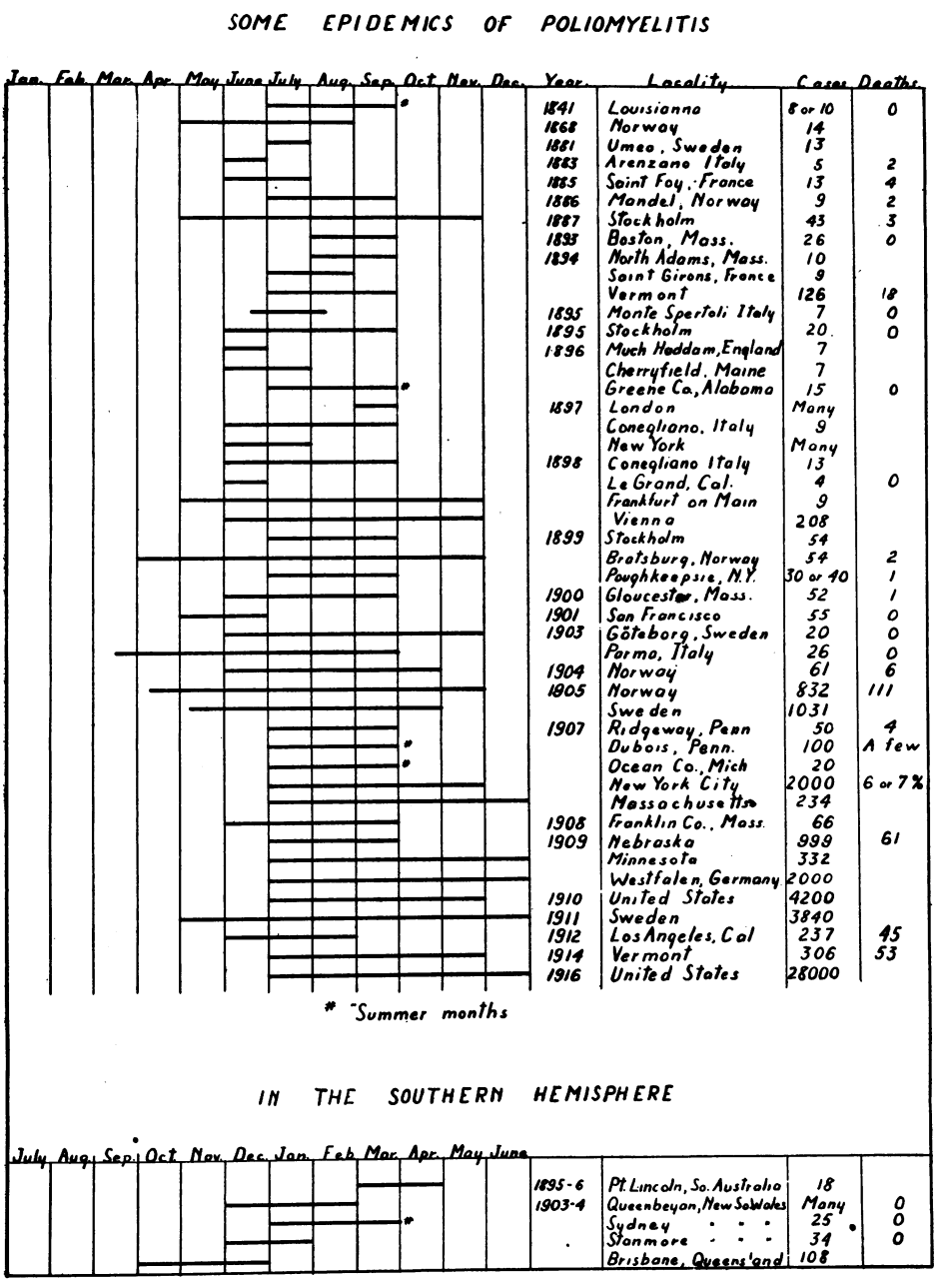


CHART 2. Records of fifty-two epidemics of poliomyelitis showing the prevalence in the warmer months.

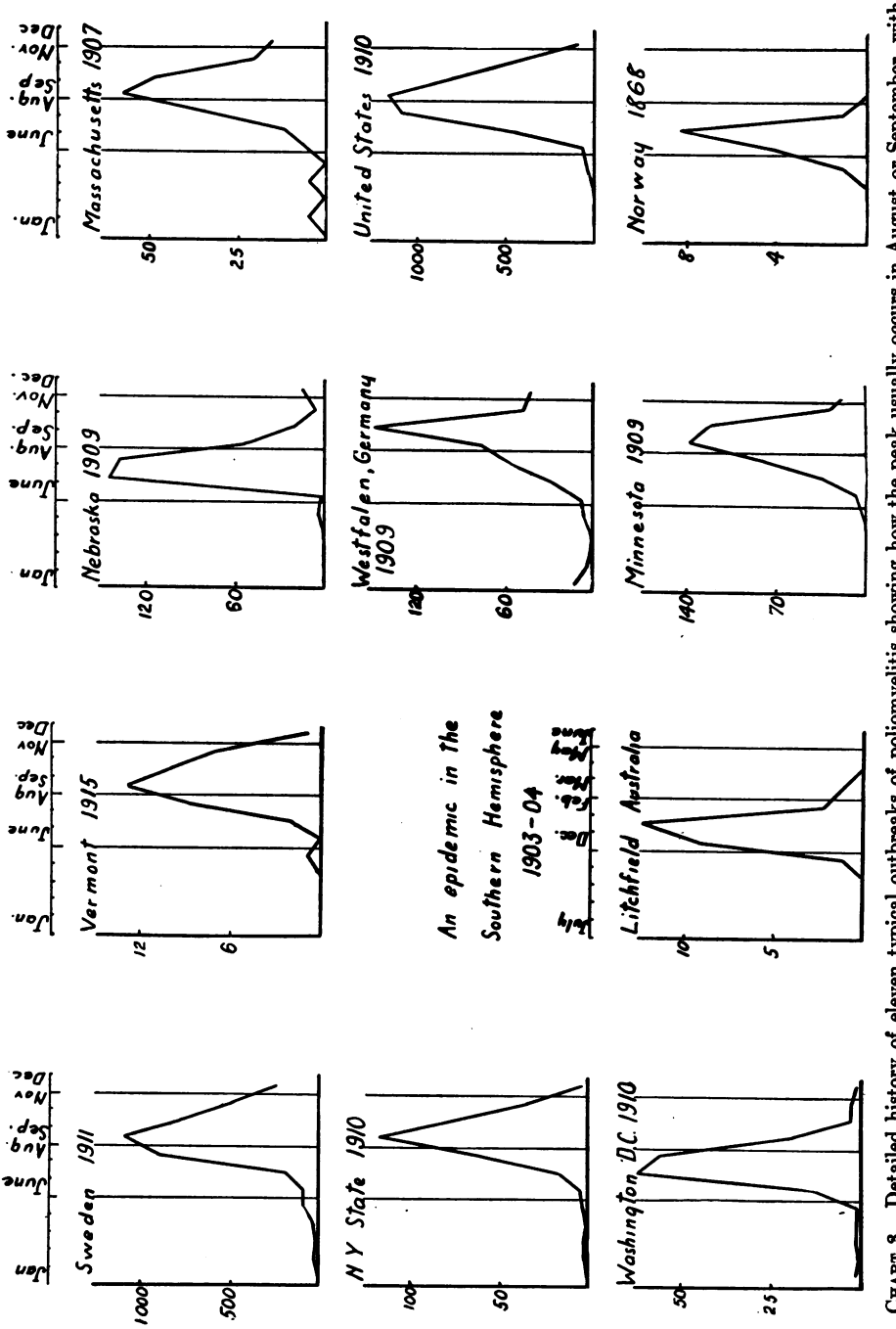


CHART 8. Detailed history of eleven typical outbreaks of poliomyelitis showing how the peak usually occurs in August or September, with all the cases between the first of June and last of November. (Southern Hemisphere first of December and last of May.)

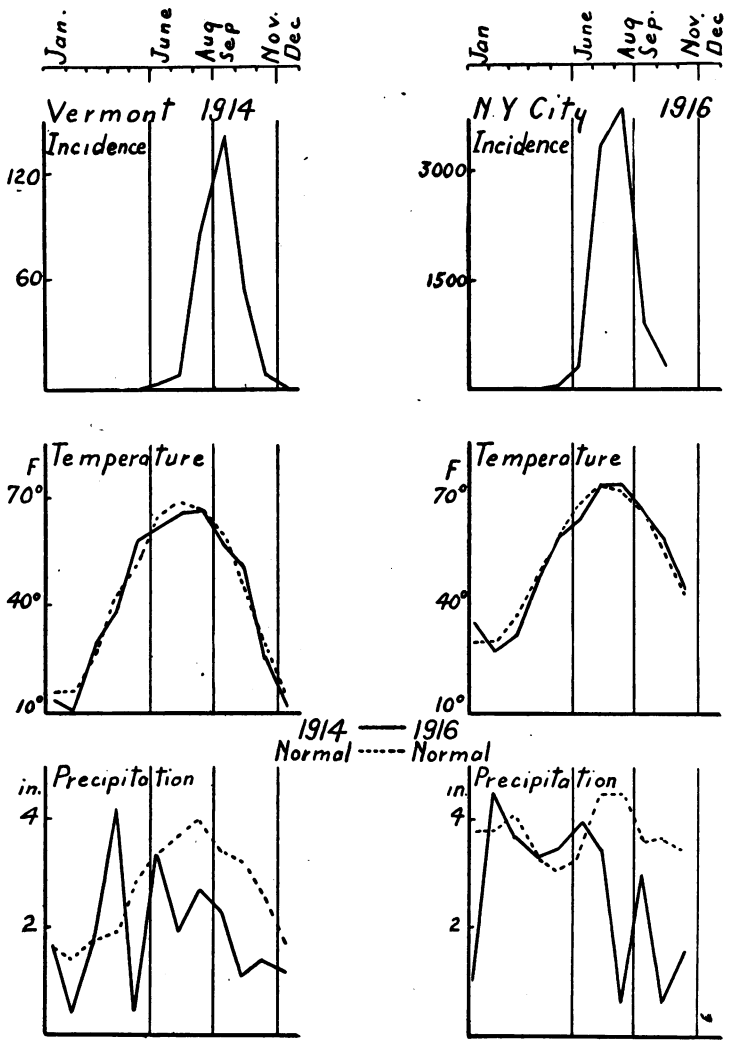


CHART 4. Relation of incidence of poliomyelitis to temperature and rainfall. Note the deficiency of rainfall during the height of the epidemics. This is typical of the large majority of epidemics.

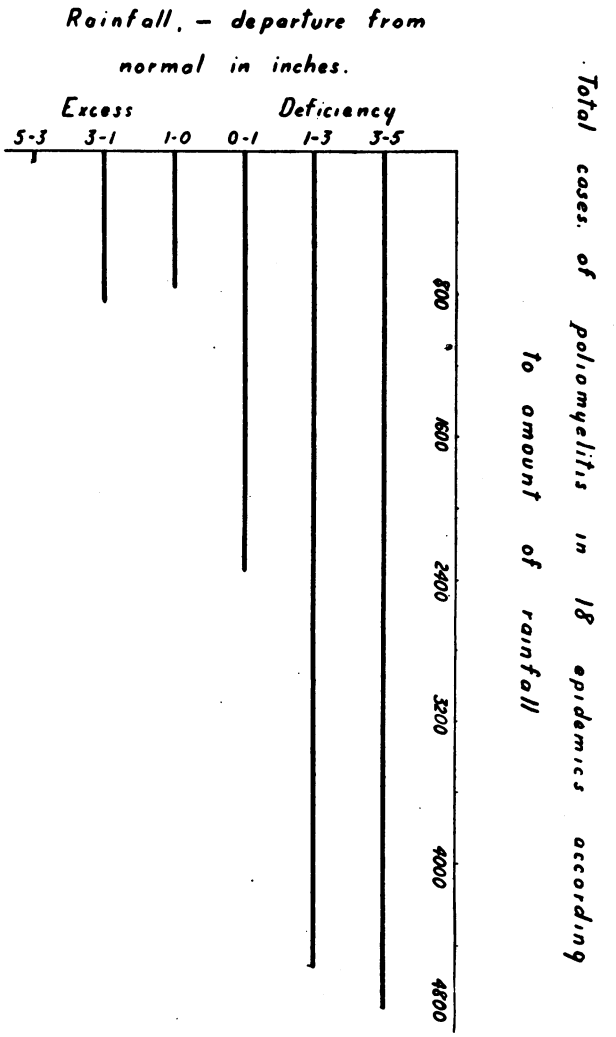


CHART 5. Relation between rainfall and incidence of poliomyelitis, showing how 11,994 cases or 90 per cent. of the total occurred during months of deficient rainfall, as against 1,371 cases in months of excess rainfall. In general, the dryer the weather in epidemics, the greater the number of cases.